NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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PREDICTING PROFICIENCY ON VISUAL SONAR DISPLAYS

Validation of a Test Battery

by

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Naval Medical Research and Development Command
Research Work Unit M0100.001-1012

Released by:

W. C. MILROY, CAPT, MC, USN
Commanding Officer
Naval Submarine Medical Research Laboratory

19 January 1983

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SUMMARY PAGE

THE PROBLEM

To validate a battery of perceptual and cognitive tests that were shown previously to predict which men were proficient operators of visual sonar displays.

RESULTS

Success in operating visual sonar displays was again predicted moderately well from a few measures which include perceptual, cognitive, and experiential factors.

APPLICATION

Recommendations for increasing the number of effective sonar operators are made on the basis of these results.

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Naval Medical Research and Development Command Research Work Unit M0100 .001-1012-- "Validation of test battery for predicting effectiveness on visual sonar displays." The manuscript was submitted on 20 Dec 1982, approved for publication on 19 Jan 1983 and designated as NavSubMedRschLab Report No. 994.

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ABSTRACT

The results of previous research suggested that a battery of 3-4 specific visual/perceptual tests could be employed to predict proficiency as an operator of visual sonar displays. This test battery was validated on a new group of An/BQQ-5 and AN/BQQ-6 sonar technicians and once again moderate multiple correlations were produced. The tests include measures of near vision, intelligence, experience and personality; their implications for maximum utilization of sonar technicians are discussed.

INTRODUCTION

Technological advances in the quality of sonar systems aboard submarines have resulted in capabilities for detection and classification of underwater objects that far exceed older systems. These advances are particularly evident in the newest generation of sonars culminating in the AN/BQQ-6. At the same time, they have resulted in a profusion of information which is displayed, primarily visually, to the operator. The extent to which the capabilities of the new systems are realized depends upon the skills and abilities of the operators of these displays. Both anecdotal evidence[1] and results from a previous assessment of sonar operators[2] suggest there are large individual differences in the ability to operate and interpret the displays.

Previous research was designed to determine whether tests of specific visual, perceptual, or cognitive factors would predict successful operators. The procedure employed was the standard one used in occupational testing: a battery of tests was given to over 100 men who were evaluated for excellence as sonar operators by an independent criterion. The tests included some 33 different measures of visual, perceptual, and cognitive abilities which were thought to be important for the operation of sonar systems. The independent criteria for proficiency were ratings by the sonar technicians themselves and by their supervisors. Multiple correlations between the test results and the independent criteria were then performed to determine which subset of the tests best predicted proficiency as an operator of visual sonar displays.

The results suggested that a battery of tests and some additional information could be effective. The specific six measures were time in service, General Classification Test (GCT), near acuity, near lateral phoria, texture discrimination, and the Internal/External attitude test. No one measure by itself gave an adequate prediction of job efficiency; together, however, multiple correlations of about .50 were achieved. Furthermore, the final group of tests quite logically came from many different areas--perceptual, intellectual, motivational, and experiential. Thus time in service is represented, showing that experience is an important factor. The GCT measures general intelligence; near acuity and phoria show the extent to which an individual's vision is adequate for the task. Texture discrimination may be an innate perceptual skill, and the Internal/External test measures job-related personality and attitudes.

The final step in the occupational testing procedure is cross-validation with a new group of men. The larger the number of variables used in a multiple correlation, the greater the possibility that the regression equation will reflect chance relationships. The term "sample-specific covariation" refers to a relationship found in one random sample but not in other samples from the same population. The result of sample-specific covariance is that a multiple correlation so based will be larger than one found in other samples from the same population.[3] Recognition of this fact is widespread among statisticians and mathematicians

and has led to both the cross-validation procedure and to a formula[4] for predicting, under ideal conditions, the amount of shrinkage of the multiple correlation when applied to a new sample.

This report therefore presents the results of giving the same, small subset of six tests to a new group of over 100 sonar technicians to determine if proficiency as an operator can again be predicted.

METHOD

The Tests

The tests were selected from the previous battery on two bases: (1) the best multiple correlation with proficiency as a sonar operator, and (2) ability to differentiate the best from the poorest operators. The complete battery was described previously,[5] and the tests used in this cross-validation follow:

Acuity and phoria - A rapid measure of acuity and phoria at both near (13 inches) and far (simulated 26 ft) viewing distances is available using the Ortho-Rater, an instrument designed for mass screening. Since in this study we were interested in near vision, many of the tests at the far viewing distance were omitted. We did, however, include far, binocular acuity in the battery since comparison of near and far acuity gives a basis for estimating type of refractive error. The specific tests included thus were binocular far acuity, monocular and binocular near acuities, and near lateral and vertical phorias.

Texture discrimination - This test, designed locally, and used previously in other studies,[6-8] is presented on a cathode-ray tube. It has obvious face-validity for the men since it presents problems similar to ones they are familiar with as sonar operators--that is, locating patterns on a screen and interacting with a computer keyboard to identify the patterns.

The patterns were composed of random dots generated by computer and presented in a rectangular display with a visual angle of 6° x 8°. The distribution of dots in one quadrant of the array was different than that in the other three. Each array was exposed for 1.5 sec. The subject's task was to decide which quadrant was different in 100 different arrays.

Attitude test - The Internal/External Test, a scale introduced by Rotter,[9] measures the extent to which an individual believes that he can control his own destiny. This measure of locus of control (personal actions versus luck, fate, chance, etc.) has been widely used[10,11] and frequently shown to correlate with job success.[12,13]

General Classification Test and Arithmetic Test - These standardized measures of verbal and arithmetical aptitudes are qualification measures for acceptance into the sonar program. The scores were obtained from the personnel records of the sonar technicians.

Age and experience - The final measures consisted of information obtained from the men: Age, rating, and years of experience in the service, as a submariner, and as a sonar technician.

Lateralized EEG - One new measure, a recording of EEGs from various cortical locations, was included in the test battery in an attempt to improve the overall prediction. This measure was developed in another research project, but employs the test of texture discrimination described above. A number of investigations have shown consistent differences in the amount of alpha in the two sides of the brain during the performance of different tasks.[14-17] A particular pattern of right hemispheric functioning is usually found with a visuospatial task.

Pertinent to the present investigation is the fact that this particular right hemispheric pattern was found in individuals who did well on the test of texture discrimination. Thus we simply added electrodes and recorded EEGs while the men were taking the texture discrimination test.

Subjects

One hundred and three sonar technicians took the tests. The aim was to obtain measures and ratings on all sonar technicians on a given submarine. The criterion for selecting a submarine for inclusion in the study was that it was fitted with either the AN/BQQ-5 or the AN/BQQ-6 sonar system and that the men had sufficient experience with the sonar system to be able to recognize the best operators.

For submarines with the Q-5 this did not present a problem. Six ships* (PHILADELPHIA, GROTON, LAJOLLA, DALLAS, ARCHERFISH, AND TINOSA) have been in the fleet for some time and the men have had sufficient experience. Seventy-four of the 103 sonar technicians were from these ships. These men tap the same population as that of the previous study, all of whom were from Q-5 submarines.

The criterion was more difficult to apply to Trident submarines since production delays had slowed their entrance into the fleet. Nonetheless, the sonar technicians of the OHIO and the MICHIGAN were tested and ratings done on the men after they had completed all of their sea-trials. Twenty-nine of the 103 men were from the Trident submarines.

Testing and Rating Procedure

The men were scheduled in small groups of one to four, briefed on the reasons for the research, and given identification numbers to ensure their anonymity. They were tested individually on the Ortho-Rater, asked about their service history, and given the opinion test. They were given instructions and 10 practice trials on the texture discrimination test. During the 100 actual test trials, which takes about 15 minutes, EEGs were recorded from O_1, O_2, T_3 and T_4 on magnetic tape for later analysis. The complete battery of tests took about an hour.

After all the men on a given submarine had been tested, ratings of proficiency were obtained from the sonar chief and from each of the sonar technicians. A sample rating scale for the sonar chief is given in Appendix A. The instructions to the sonar chief were as follows:

"You are being asked to rate the sonarmen on your ship for over-all ability as an operator of visual displays. (This does not include

*Some of these submarines participated in the original validation, but there has been a complete change of crew in the intervening years.

skills in the maintenance or repair.) Simply make a check under each name at the position where he falls on the scale. Rate every man with respect to all others and also with respect to your general knowledge of sonar operators. After you have gone through the names once, look back over it to make sure there are no inconsistencies. Feel free to make any changes you wish.

In any small group of men, such as the sonar crew, there is only a small chance of having some one really great or terribly poor. Generally there will be several men who are about average and perfectly acceptable. It is often easiest to start the rating with these average men and then ask yourself how much better or poorer the other men are."

Proficiency measures were also obtained from each of the sonar technicians by a different technique. The men were asked simply to nominate in order of excellence those three individuals that they believed to be the best over-all operators of the Q-5 or Q-6 on their ship. They were told to use all aspects of operating the sonar system, such as detection and classification, in their evaluation but not to include maintenance and repair.

The peer nominations were evaluated by assigning an arbitrary value of 3 to the man rated highest, 2 to the next best,and 1 to the next. The sum of all values awarded to each technician by his peers was used as the basic measure of his proficiency. This sum was then converted to the percent achieved, out of the total score possible, to equate for differences in the number of men rated on different ships.

Both of these techniques, ratings by the sonar chief and peer nominations, were used as the independent criteria in the previous validation.[2] The agreement between the two measures was excellent, and the use of one or the other as the independent criterion made no difference as to which tests were included in the battery.

RESULTS

The Independent Criterion of Proficiency

Results of the previous study showed excellent agreement between the ratings by the peers and by the sonar chiefs when analyzed in several different ways. Since the rating procedures were identical in the two studies, the same analyses were performed.

Figure 1 shows the frequency distributions of ratings of the 12 men on a typical submarine. The distributions differ due to the different procedures employed. Rates by the sonar chief approach a normal distribution, but the distributions of peer nominations are quite skewed: on each submarine only a few men received most of the votes while many men obtained none. The hatched and solid areas in the distributions show the agreement between the ratings. The five men rated poorest by the sonar chief are among the six men who received zero nominations by the peers. Four of the five men rated best by the sonar chief were the four top operators according to the peers; the fifth ranked sixth in the peer distribution. Thus while the distributions differ in shape, the general agreement is excellent.

Correlations between chiefs' and peers' ratings, determined separately

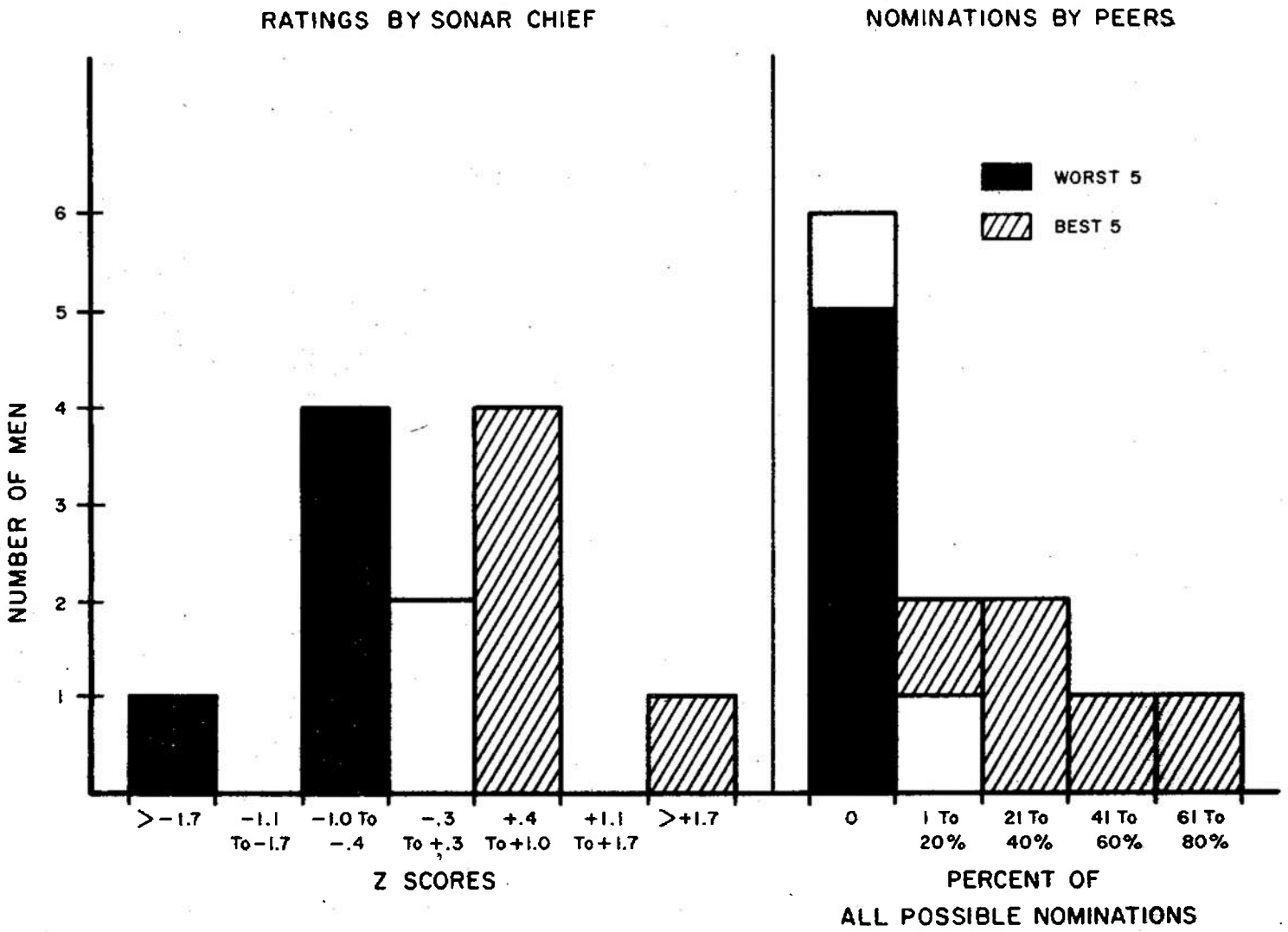

Fig. 1. The distribution of proficiency ratings for the 12 sonar technicians on a typical submarine. The shaded areas indicate the degree of agreement between ratings by the sonar chief and nominations by peers.

Table I. Comparison of ratings of proficiency by peers and sonar chief

Submarines	Rank-order Correlation	Comparison of ranks of most nominated man	
		by Peers	by Chief
Q-5			
Philadelphia	.85	1	2
Groton	.88	1	1
La Jolla	.27	1	3.5
Dallas	.80	1	2
Archerfish	.90	1	1
Tinosa	.61	1	6.5
Q-6			
Ohio	.81	1.5	1.5
Michigan	.48	1	2

for each submarine are given in Table I. Rank-order correlations were used due to the skewed distributions of the peer nominations. Most of the correlations are very high, quite comparable to those of the previous investigation. There were two notable exceptions: one attack submarine and one Trident have poor correlations, and there were significant discrepancies between the ratings: for example, a sonar technician rated in the top three by his peers was near the bottom in the evaluation by the sonar chief. It is worth noting, however, that these are the two newest submarines in the fleet. The MICHIGAN, in fact, had had no real sea experience except for trials prior to commissioning.

A comparison of the ranks of the best men on each submarine is also given in Table I. In six out of eight cases, the men who received the highest percentage of possible nominations by his peers was also rated first or second by his chief.

It would thus appear that, with a few exceptions, the differences between sonar chief and peer ratings of proficiency are minor. Also the few exceptions may well be due to insufficient time at sea to assure stable judgments.

Comparison of Q-5 and Q-6 Operators

A comparison of the mean scores achieved by Q-5 and Q-6 operators on each of the tests is shown in Table II, together with the mean values for the total group. There are no significant differences between the

Table II. Comparison of mean results of AN/BQQ-5 and AN/BQQ-6 operators

Tests	Total Sonarmen N=103	Q-5 Operators N=74	Q-6 Operators N-29
Acuity $\frac{1}{\text{(min.vis.angle)}}$	1.12 ±.11	1.12 ±.11	1.13 ±.13
Phoria	-4.05 (exo)±4.2	-3.90 ±4.2	-4.35 ±3.9
Texture errors	44.2 ±9.6	44.2 ±9.8	44.3 ±9.2
Internal/External Test	7.9 ±3.5	7.8 ±3.6	8.3 ±3.2
GCT	58.9 ±6.2	58.9 ±6.4	59.0 ±5.6
Experience Variables:			
Age	24.4 ±4.5	23.6 ±4.2	26.5 ±4.8
Months in service	61.9±45.9	52.2 ±37.9	86.6 ±55.3
Months in subs	50.1±46.6	41.0 ±40.9	73.3 ±52.7
Months as Sonar technician	52.1±45.3	42.5 ±35.5	76.7 ±57.5

two groups on acuity, phoria, texture discrimination, the opinion test, or the GCT. However, the Q-6 operators are significantly older ($t=2.3, p<.05$), have more time in service ($t=3.0$, $p<.01$), more time on submarines ($t=3.3$, $p<.01$) and have served as sonar technicians significantly longer ($t=2.9$, $p<.01$).

The result at first appears unusual since the Q-6 is new and just now being used on the first Tridents in the fleet; most of the men thus were trained on the Q-5. However, the majority of our Q-6 operators were from the first Trident and all were from the first two. It is quite likely that these men were specifically selected for this position and represent a particularly experienced and competent group of sonar technicians.

Multiple Correlations Between the Test Battery and the Independent Criteria

Multiple correlations between the six measures (near acuity, near lateral phoria, time in service, texture discrimination, the I/E opinion test, and GCT score) and the ratings for proficiency as a sonar operator were obtained; the values are given in Table III. Three different criteria are listed, the ratings by the sonar chief, the ratings by the peers, and the average of the ranks by the chiefs and peers. The latter is included as an estimate of the operator's proficiency because of the occasional disagreement between the chief and peers.

For the total group, the correlation between the measures and the sonar chiefs' ratings was $r=.44$

Table III. Multiple correlations determined separately for AN/BQQ-5 and AN/BQQ-6 operators

Criterion Sonar Technicians	Multiple r		Total Group
	Q-5 N=74	Q-6 N=29	N=103
Chiefs' rates	.512	.530	.440
Peers' rates	.276	.492	.261
Mean ranks by Chief & Peers	.421	.431	.301

and the peer ratings, r=.26. The correlation of r=.44 is significant at better than the $p < .01$ level and is in fact almost exactly predicted by the previous results. McNemar's formula for predicting shrinkage in a new sample, under ideal conditions, yields a value of .44 for the second sample when the original correlation is .50. The correlation of .26, for the peer ratings, is somewhat less than the predicted value of .35.

When the multiple correlations are computed for the Q-5 and Q-6 operators separately, they are invariably higher than that of the total group. The likely reason for the increased correlations is that the Q-5 and Q-6 operators really represent two different groups, because of the differences in age and experience referred to earlier. Since all proficiency ratings are made within single submarines, it is possible that some of the poorer Q-6 operators are superior to some of the better operators on one of the Q-5 submarines. Separating them thus improves the correlation, and makes them comparable to that of the previous study.

Measures of Predictive Value for Sonar Operators

As in the previous investigation, no single measure had a sufficiently high correlation to be an adequate predictor, and a battery of tests is required for a successful multiple correlation. However, some of the six measures in the battery contributed more than others to the correlation or were more consistently related to proficiency. This is illustrated in Table IV which gives the correlations of individual measures with the criterion; again the values for chiefs' and peers' rates were averaged to give the best estimate of proficiency. Each of the measures and its implications for selection of sonar operators is discussed in turn.

Acuity - Near binocular acuity is once again positively correlated with operator proficiency, although the correlation is not so large as previously. Actually, only a few men, seven out of the 103, have subnormal (less than the equivalent of 20/20 at near) near binocular acuity. Most of these probably have uncorrected or inadequately corrected hyperopia or astigmatism; four of

Table IV. Average correlations of single items with the criteria

Test	Q-5 N=74	Q-6 N=29	Total N=103
Acuity	+.046	+.091	+.053
Phoria	-.048	+.110	-.010
Time in Service	+.294	+.208	+.230
Texture Discrimination	+.010	+.258	+.066
I/E Opinion	-.172	-.194	-.179
GCT	+.200	-.192	+.109

the men do not wear glasses at all. Interestingly, a disproportionate number of these men fall into the groups of poor operators. For example, six of the seven are in the group that received zero nominations from their peers. Thus even though the correlations with proficiency are very small, we recommend that near vision be tested and corrected if necessary. It is a very simple corrective action and should eliminate problems for those few individuals who need it.

Phoria - Phoria measures can deviate from normal either by yielding small values on the Ortho-Rater (esophoria) or large values (exophoria). In the previous investigation the poor operators had more exophoria, and that is the direction for the Q-5 operators. The present correlation however is very small and insignificant. However a disproportionate number of men with exophoria also have poor near acuity. Thus, correcting the near vision of the few individuals that need it should also solve the problem of exophoria and eliminate it as a factor in poor performance.

Time in Service - This measure of experience was the best predictor in the previous investigation and maintains that status in the present validation. The finding that experience and training are important is not helpful to the selection process. However it does suggest that any procedure that reduced the need for extensive training would ultimately be of benefit, leading toward the goal of increased numbers of proficient sonar operators.

Texture Discrimination - The measure of texture discrimination employed is the number of errors made on the test, so that the small positive correlation is in the wrong direction: that is, the better operators made more errors. This was true in the previous investigation for one of the measures of texture, while the other measure had a negative correlation. The usefulness of the test would thus seem limited and we propose its elimination from the battery unless the reason for the negative correlation is determined. One possible reason is that texture discrimination

represents an immediate visual response that does not require the analytical perception needed for sonar displays.

The Internal/External Opinion Test - This test consistently was correlated with ratings of proficiency, both for the ratings by the chief and by the peers and for the Q-5 and Q-6 operators. The negative correlation stems, of course, from the fact that the smaller the score on the test, the more internal the locus of control; thus the more internal individuals tend to be the more proficient operators. The result is the same as found in the previous study; the present correlations are in fact somewhat higher. This same result is found repeatedly in the literature: the individual who perceives himself to be in control of his life shows more initiative and effort, achieves greater success and feels more satisfied than the individual who does not.[12] While this personality characteristic is obviously important for an effective sonar operator, there are at least two techniques by which it could be achieved. Men could, of course, be selected on the basis of the Internal/External Test results. Even better would be the possibility of helping an individual achieve this outlook, through training and experience. There is in fact considerable evidence that the perception of control is based upon past experience and can be changed by the nature of the job and its supervision.[13,18]

General Classification Test - GCT had one of the higher correlations with proficiency in the previous investigation and is correlated in this study at about the same level for the Q-5 sonar technicians. Interestingly, the correlation reverses for the Q-6 operators. The negative aspect is, of course, meaningless: it is not significant for an N of 29 and is the result of one man with a low rating and much service time. Nonetheless, the fact that there is essentially no correlation for experienced technicians is of interest. It suggests that intelligence is of importance primarily for individuals while thay are learning to be operators.

EEGs Recorded During Texture Discrimination - Theoretical considerations and previous research suggest that visual-spatial processing is successfully performed in the right hemisphere and that this in turn differentially reduces the amount of alpha in that hemisphere.[14-17] Therefore a laterality index, (R-L/R+L), where R is the amplitude of alpha activity recorded in the right hemisphere and L the alpha in the left hemisphere, was computed for each subject. Comparison of the indices of the best and poorest operators, by any criterion, did show that the better operators had more negative indices. Furthermore, multiple correlations between the tests and criteria were improved by the addition of the electrophysiological data. Since the EEGs were not part of the original test of sonar operators, these data will be presented in a separate paper. It should be noted here, however, that it does represent a promising new tool for prediction of proficiency as a sonar operator.

SUMMARY

Once again, many factors contribute to proficiency as a sonar operator of visual displays. The factors include the subjects' experience and training, intelligence, personality,

and vision. The validation, using a new group of men, has been successful in that proficiency can be adequately predicted by the same battery of tests as with the previous group of sonar technicians. The application to the selection of men is, however, not straightforward.

One cannot use prior experience to select new operators. It is also not feasible to further increase the GCT requirement. A GCT one standard deviation above average is already a selection criterion for sonar technicians; further increases would drastically reduce the number of available men. Knowledge of the important factors, however, can be important since they suggest the areas in which improvements could be made. The following recommendations stem from this knowledge:

1) Sonar technicians should be corrected for near vision. Although near vision is routinely checked by most optometrists and ophthalmologists, no separate correction is usually given unless the individual is older and becoming presbyopic. Giving near vision correction to those few sonar operators who need it should be an easy and worthwhile procedure.

2) Training in responsibility and expectations of control over one's actions should benefit performance by sonar technicians.

3) Considerable effort should be put into research and development of sonar systems which are easy to operate. Modern systems require highly experienced and very intelligent operators. The best way of increasing the pool of successful sonar operators is to build a system for which these requirements are not so necessary.

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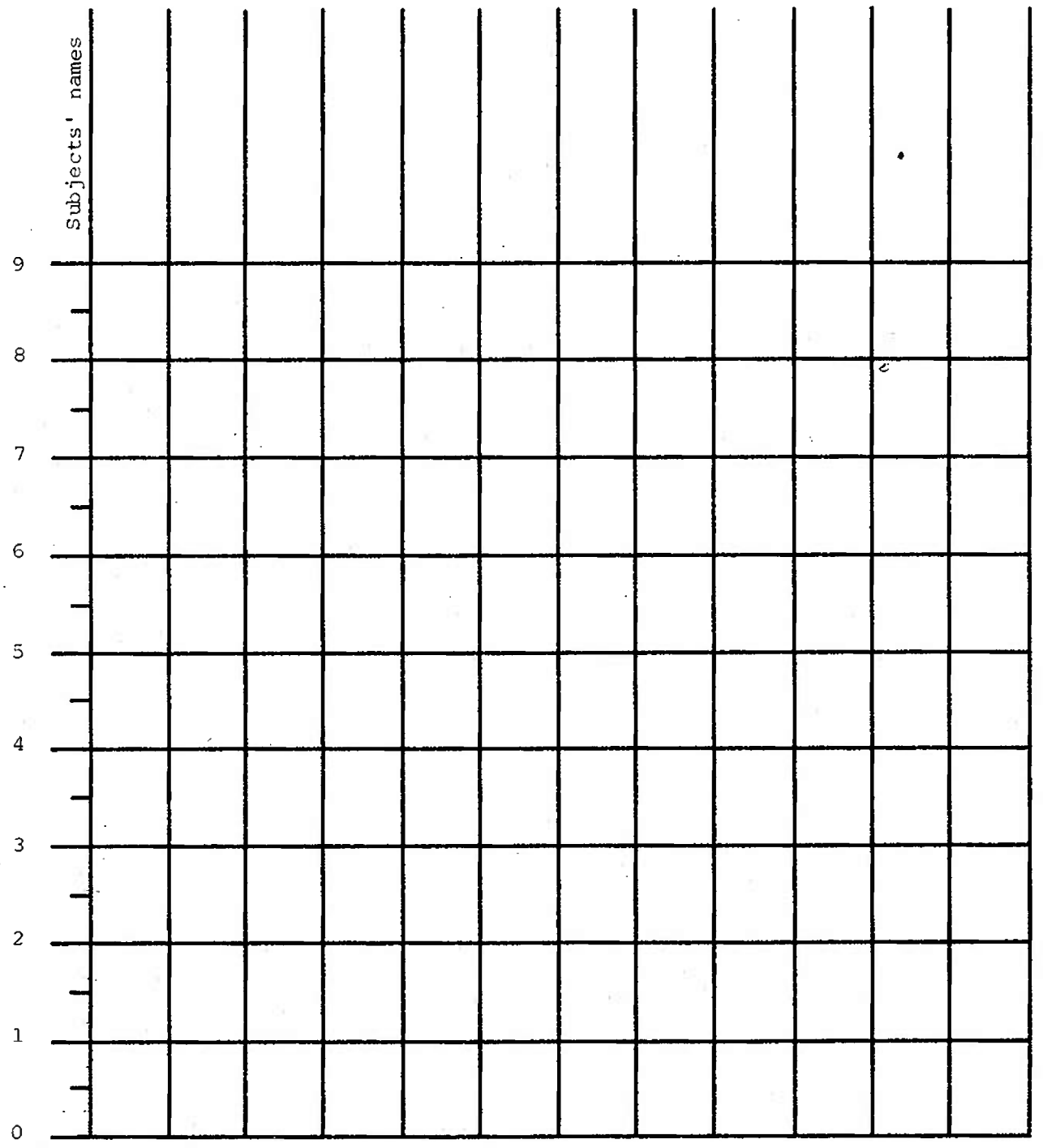
APPENDIX A. Rating Form Used by Sonar Chief



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Near vision; sonar operators; multiple correlations; validation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The results of previous research suggested that a battery of 3-4 specific visual/perceptual tests would be employed to predict proficiency as an operator of visual sonar displays. This test battery was validated on a new group of AN/BQQ-5 and AN/BQQ-6 sonar technicians and once again moderate multiple correlations were produced. The tests include measures of near vision, intelligence, experience and personality; their implications for maximum utilization of sonar technicians are discussed.

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